

## CONTROL SYSTEM FOR VARIABLE PITCH FAN PROPULSOR

### BACKGROUND OF THE INVENTION

This invention relates to control means for an aircraft propulsor of the class known as Q-Fans<sup>TM</sup> being developed by the Hamilton Standard Division of United Aircraft Corporation and particularly to coordinated means for controlling the pitch of the fan blades, engine fuel flow and fan exhaust nozzle area.

To more fully understand the Q-Fan<sup>TM</sup>, reference should be made to U.S. Pat. No. 3,747,343 granted to Mr. George Rosen and assigned to the same assignee. As is the case with all controls for gas turbine power plants, it is customary to provide means for monitoring engine operations and provide control means to convert those signals to a logic that will provide, as best and efficient as possible, optimum engine operations. Thus, the control manifests these signals to provide fast thrust response during take-off and landing, optimum TSFC (Thrust Specific Fuel Consumption) in all cruise conditions, while preventing stall or surge, rich or lean blowout, overtemperature, overpressure and overspeed conditions.

Obviously, the incorporation of such variables as variable pitch fans, variable area fan exit nozzles and the like will add complexity to the control system. The significance of this invention is to provide a reliable coordinated control that coordinates fuel flow to the gas turbine engine and pitch change of the fan blades and the area of the variable exit nozzle of the bypass duct so as to achieve rapid thrust modulation in takeoff and landing modes and optimum TSFC in all cruise and long duration flight conditions while providing the typical protection to the gas generator. In particular this invention contemplates biasing the power lever schedules with flight Mach No. to provide control of engine fuel flow, fan pitch and area of the exit nozzle in the event this variable is included. The surge of the fan is prevented by defining a scheduled exhaust nozzle area which is a function of flight Mach No. and corrected engine fan speed ( $N_2/\sqrt{\theta}$ ) and feeding it to a selector circuit that selects the larger of the normal scheduled area and the minimum fan exit area which is required to avoid fan surge. The fan exit area nozzle is also utilized to optimize performance (TSFC) for long duration flight conditions. Except for the condition lever which is typically employed in aircraft for starting, shutting-off and feather, this invention contemplates a single power lever that is so coordinated to provide engine fuel flow, variable fan pitch change and variable area exhaust nozzle control.

This control also contemplates the aspect of reversing the pitch of the fan through feather as opposed to passing through flat or zero pitch. This presents a significant problem since the pitch of the fan just prior to reversing is at a lower positive blade angle and must move to a higher positive blade angle to reach the feather angle position. Without anything else being done the higher positive pitch will increase the blade loading and produce a higher positive thrust which is obviously undesirable inasmuch as this increases forward flight velocity where a decrease is required. Of course, once in reverse pitch, maximum reverse thrust is obtained. To achieve this end we have found means to coordinate the functions of engine fuel flow, blade angle and exhaust nozzle area so as to minimize forward

thrust by judiciously reducing and increasing fuel flow and/or increasing exit fan nozzle area and optimize the transient response.

Thus, in summary, without limiting the scope of this invention the salient features are:

1. The ability to schedule optimum conditions and minimize TSFC at all thrust levels in the Mach number range where extended flight conditions are expected by coordinating fan pitch, fan exhaust nozzle area and engine fuel flow.

2. The ability to provide rapid thrust response in the takeoff and landing conditions by coordinating fan pitch and engine fuel flow so as to optimize transient response characteristics.

3. Provisions for shutting off fuel flow and feathering fan blades to prevent fan rotation and excessive drag in the event of engine malfunctions.

4. The ability to modulate thrust smoothly from maximum to near zero thrust in both the forward and reverse range on the ground.

5. Conventional acceleration and deceleration, overtemperature, overspeed and overpressure limits are incorporated into the gas generator control system to prevent operation outside of the normal envelope.

### SUMMARY OF THE INVENTION

An object of this invention is to provide an improved control for a propulsor powering aircraft.

A still further object of this invention is to provide control means that coordinates fuel flow to a gas turbine engine driving a variable pitch ducted fan and the pitch of the fan.

A still further object of this invention is to provide control means that coordinates fuel flow, pitch change of the gas turbine engine driven fan and the exhaust nozzle area of the bypass duct surrounding the fan.

A still further object of this invention is to provide control for a propulsor of an aircraft which coordinates the pitch of a variable pitch fan and fuel flow to the gas turbine engine by biasing power lever position as a function of Mach No. Additionally, the control anticipates changes in fan pitch and schedule changes in fuel flow so as to minimize fan speed excursions and to optimize thrust response characteristics. The control provides additional coordinating means for controlling the area of the exit exhaust nozzle of the bypass duct housing the fan, if incorporated.

A still further object of this invention is to provide surge prevention means of the fan by controlling the area of the fan exhaust duct nozzle as a function of Mach. No. and corrected fan speed.

Other features and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate an embodiment of the invention.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view, partly in section and partly diagrammatic illustrating the preferred embodiment.

FIG. 2 is a diagrammatic illustration of this invention.

FIG. 3 is a diagrammatic illustration of the anticipation circuitry.

### DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is now made to FIGS. 1 and 2 which illustrate the preferred embodiment of this invention showing